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ABSTRACT

The first half of a Biomedical Engineering course at Texas A&M University is devoted to group projects that require design planning and a search of the literature. The second half requires each student to individually prepare a research proposal and conduct a research project. (MLH)

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TITLE OF PAPER An Undergraduate Two-Course Sequence in Biomedical Engineering Design: A Simulation of An Industrial Environment With Group and Individual Project Participation

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Introduction:

Formal training in engineering analysis and design has been a traditional feature of most undergraduate engineering curricula. Typically, a three-hour lecture or project course provides the framework for student training in this essential engineering function. Engineering design courses are normally sequenced near the end of a four- or five-year program so that an integration of engineering fundamentals can be achieved in one or more student design projects.

The implementation of an effective analysis and design course for an undergraduate bioengineering curriculum offers a unique challenge for the following reasons: Firstly, the technological base for this field is considerably more comprehensive than traditional engineering specialties ranging from formal coursework in the life sciences to a number of engineering specialty courses in bioengineering. (An example of the diversity in coursework is reflected in the outline of the Bioengineering Program at Texas A&M University given in Table 1.)

Texas A & M University
Undergraduate Bioengineering Curriculum (1975)

Engineering Sciences:	Physics: Electricty, Electronics, Mechanics
	Chemistry: General, Physical, Organic
	Mathematics: Calculus, Differential Equations
	Materials Science
	Computer Science
Bioengineering Specialty:	Life Sciences: Physiology, Anatomy, Biochemistry
	Biomedical Instrumentation
	Bio-Transport Phenomena (Mass, Heat, Fluids)
	Biomechanics
	Biomaterials
	Bio-Control Systems
	Bio-Thermodynamics and Kinetics
	Analysis and Design Project

Table 1

The diverse nature of previous coursework and the broad nature of the field of bioengineering in general results in student interest in a wide variety of project areas. Implementation of a wide variety of projects of a significantly different nature requires the establishment of a quite versatile student laboratory in terms of facilities and equipment.

A second challenge is realized in the process of establishing analysis and design course objectives. Among those objectives which are desirable for inclusion in any such course are the following:

1. Enhancement of personal motivation to invention and innovation in engineering analysis and design
2. Integration of engineering science fundamentals in the solution of practical problems
3. Development of the ability to define problems and generate alternative approaches for solution
4. Experience in working with deadlines and routine reporting of progress
5. Development of communications skills (written and oral)
6. Development of confidence in accepting responsibility for the solution of a new problem

In addition to these more general objectives, additional goals related to the nature of student participation in design activities may be specified. In particular, for student team and individual project participation, the following additional goals may be identified:

7. Team participation: development of the ability to function effectively as a professional team member
8. Individual participation: (a) development of personal independence and confidence in problem solving abilities
   (b) introduction to independent engineering research (graduate study)

Given that the above are all worthy objectives for an undergraduate analysis and design course, time constraints usually necessitate a focus on a few with a peripheral emphasis on others. However, a recent survey

of undergraduate bioengineering training programs (1) demonstrates that significant numbers of graduates enter private industry, employment in medical centers, and graduate study in bioengineering and medicine. Therefore, the analysis and design course should provide students pursuing any of these post-graduate endeavors with an experience which will be useful in his or her professional function. In order not to sacrifice completeness of the student experience in bioengineering analysis and design (particularly in view of the wide diversity of program graduate professional activities) all of the above objectives were weighted equally and established as course goals.

Course Implementation:

The adoption of the above broad list of objectives precluded a simple course design. In particular, it is evident that to foster both team and individual project participation in a significant student experience requires an optimized sequence of instructor and student activities in an expanded time frame. Consequently, a two-course sequence in bioengineering analysis and design (BE 441 and BE 442) was established and inserted into the senior year coursework as indicated in Table 2.

Thus, by utilizing the framework of a two course sequence, it was possible to focus one course on a student team project and the other on individual student projects. In addition, an expanded time frame allows for the formal treatment of topics that a designer needs but which are normally not covered elsewhere in a typical engineering curriculum. The overall organization of the Bioengineering (BE): 441-442 sequence is depicted in Figure 1.

Texas A&M University
Bioengineering Senior Year (1974-5)

Fall Semester	credit hours
BE 401 Biological Control Systems	3
BE 421 Biomechanics & Biofluids	3
BE 441 Analysis & Design Project	3
BiCh 410 Biochemistry	3
BiCh 412 Biochemistry Lab	1
Humanities or Social Studies elective	3
Tech. Elective	3
Total semester credit hours	19

Spring Semester	credit hours
BE 412 Biophysics & Biochemical Thermodynamics	3
BE 422 Mensuration & Properties of Biomaterials	3
BE 442 Analysis & Design Project	3
BE 452 Mass and Energy Transfer in Biosystems	3
BE 482 Seminar	1
Humanities or Social Studies elective	3
Total semester credit hours	16

Table 2

Owing to the complex and time-consuming nature of a student team project, the "on-paper" design process is emphasized in BE 441. Bioengineering 442 complements this limited team project experience with the requirement for the individual projects to emphasize laboratory work where feasible.

Overall Organization For BE 441-2 Two Course-Sequence

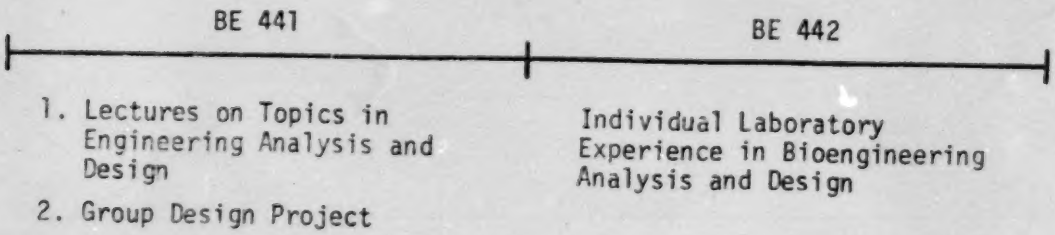
BE 441
BE 442
1. Lectures on Topics in Engineering Analysis and Design
2. Group Design Project
Individual Laboratory Experience in Bioengineering Analysis and Design

Figure 1

In order to include training in employment search techniques, BE 441 begins with a requirement for the students to prepare a personal resume and a letter of inquiry regarding possible employment. After "confirmation of employment", a suitable biomedical engineering design project (e.g. hemodialyzer, oxygenator design, etc.) is assigned the student group (ideally about eight individuals). Simultaneously, during the first one-third of this course, lectures on selected topics in engineering design (e.g. product specifications, feasibility study, patents, etc.) are presented, while the students conduct a literature survey and decide on a design concept. At the end of this introductory period, a student team leader is selected and the group (with the aid of the course instructor, as required) is divided into two-man sub-groups associated with the major aspects of the overall design assignment (e.g. physiological considerations, hardware selection, analytical modeling, etc.).

For this initial course, the formal requirements which are designed to enhance the students' ability to communicate effectively, include individual weekly progress reports, individual oral and written reports on selected aspects of the overall project, and a final team project report. The detailed organization of BE 441 is given in Figure 2.

To complement the team experience gained in the first course, and to provide a medium for introduction to independent research and development, the second course (BE 442) requires individual student effort on a suitable project (selected by the students or instructor). In order to insure advanced planning from both the students' and instructor's points of view, students are required to prepare a brief proposal for their individual projects for BE 442 during the course of BE 441 (see Figure 2). Course

Outline of BE 441

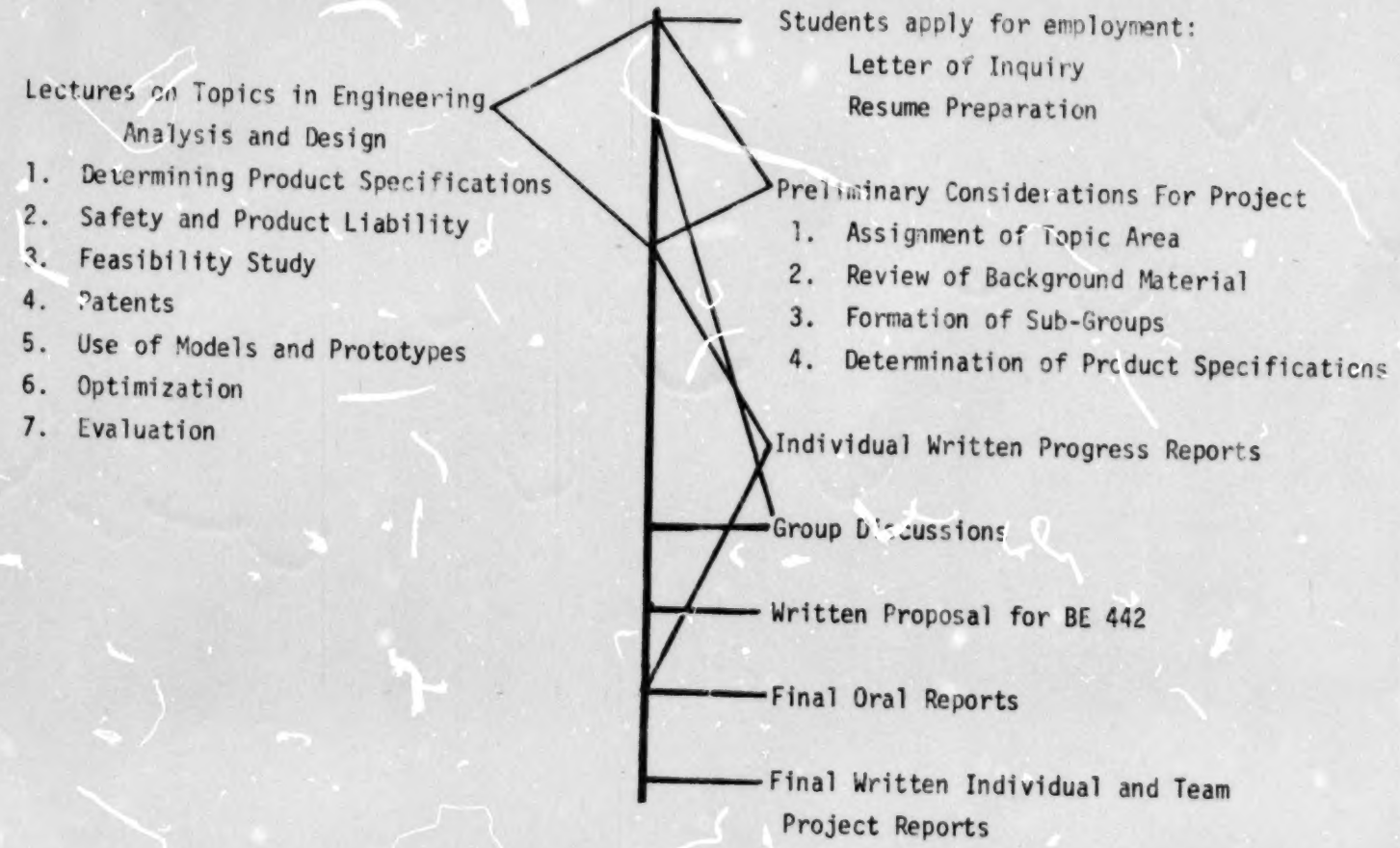
Lectures on Topics in Engineering Analysis and Design
1. Determining Product Specifications
2. Safety and Product Liability
3. Feasibility Study
4. Patents
5. Use of Models and Prototypes
6. Optimization
7. Evaluation
Students apply for employment:
Letter of Inquiry
Resume Preparation
Preliminary Considerations For Project
1. Assignment of Topic Area
2. Review of Background Material
3. Formation of Sub-Groups
4. Determination of Product Specifications
Individual Written Progress Reports
Group Discussions
Written Proposal for BE 442
Final Oral Reports
Final Written Individual and Team Project Reports

Figure 2

requirements for BE 442 again emphasize communication abilities and include periodic (2-3 week interval) alternating oral and written progress reports and a final written report. The detailed organization of BE 442 is depicted in Figure 3.

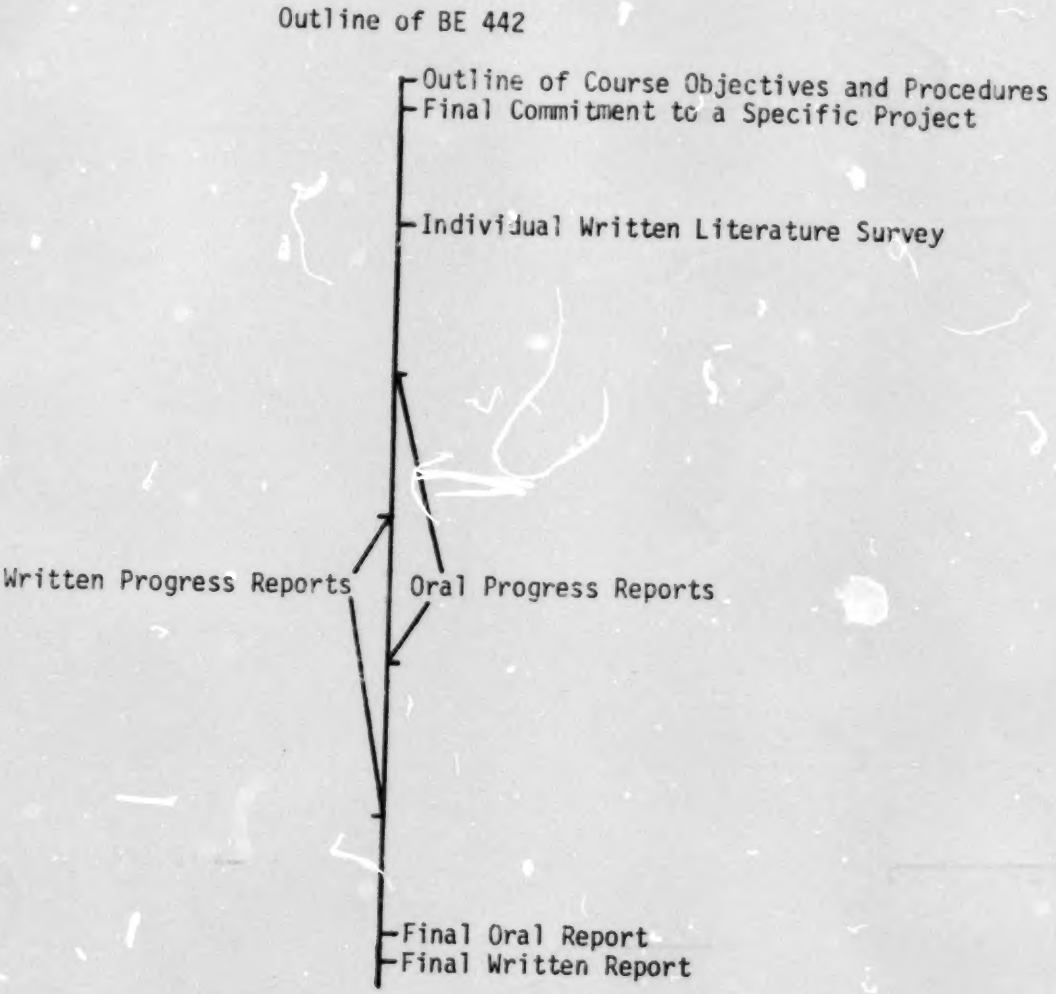
Outline of BE 442
Outline of Course Objectives and Procedures
Final Commitment to a Specific Project
Individual Written Literature Survey
Written Progress Reports
Oral Progress Reports
Final Oral Report
Final Written Report

Figure 3

In generating a list of suggested topics for individual student projects, it was realized that a significant fraction of students is expected to pursue graduate study as indicated above. Therefore, the topics list suggested by the instructor is designed to include some projects which are of a research rather than of an engineering design nature. Thus, for students with an early commitment to graduate study, the individual projects for BE 442 can serve as an introduction to independent graduate research. A typical list of student projects undertaken for BE 442 is given in Table 3.

BE 442: Individual Projects, Spring 1975

A. Design/Development
   1. Design of a Digital Speed Control For A Phonically Controlled Motorized Wheelchair
   2. Information Exchange in a Rehabilitation Institute: System Analysis and Improvement
   3. Design and Development of a Fast Response Electronic Thermometer
   4. A Feasibility Study of Hematocrit Measurement By Photometry
   5. A Computer Assisted Patient Monitoring System For Post-Operative Care
   6. A Feasibility Study of Monitoring Patients' Movement in Bed With Pressure Tape Switches and Temperature Sensors

B. Research
   1. An Investigation of the Effects of Mechanical Stress On Crystalline Hydroxyapatite Solubility
   2. Variables Affecting Hemolysis of Red Blood Cells in Hypertonic Media

Table 3

Course Grading:

Final grades for BE 441 are determined from the distribution of total points accumulated among 100 possible according to the following breakdown:

Examination on lecture topics	10
Individual written progress reports	15
Individual written proposal for BE 442	10
Individual final oral project report	15
Individual written project report	20
Team final written project report	30
	100 points possible

The rationale for this distribution is as follows: firstly, the examination on the lecture topics was inserted to motivate students to complete reading assignments on the special topics while pursuing the more immediately interesting team project. Motivation for a co-operative team effort was supplied by associating a significant proportion of the final grade with the "final team product." Since individual final grades must be assigned, fully 60% of the final grade for an individual is assigned on the basis of individual performance on written and oral reports.

The grading scheme for the second course in the sequence, BE 442 was as follows:

3 Individual interim written progress reports	30 (10 points each)
2 Individual interim oral progress reports	20 (10 points each)
Final individual oral presentation	20
Final individual written project report	30
	100 points possible

The emphasis in formulating the latter grading scheme was twofold: (1) Equal weighting is given to frequent reporting in order to maintain continuous student effort in the face of irregular demands related to other

concurrent coursework and (2) the development of skills in both oral and written technical reporting typical of routine progress reports required in many industrial settings is promoted.

Student Feedback:

Based on an initial offering in the 1974-5 academic year, student response to the bioengineering design course sequence described may be summarized as follows:

BE 441:

1. Without exception, students completing this course felt the team project concept was a valuable educational experience. The relatively high degree of course organization was thought to be essential to project success.
2. Most students felt relatively uninterested in the lectures on special topics in engineering design. It was concluded that these presentations would be more enthusiastically received if integrated into the group design project in future offerings.
3. Some students expressed the view that enhancement of creativity within the student group requires their independent function and a minimization of interaction on the part of the course instructor.

BE 442:

1. The majority of students completing this course, expressed the view that the individual project was an appropriate complement to BE 441.
2. The majority of students objected to the high frequency of progress reporting but in retrospect this was felt essential to maintain student effort throughout the semester.

3. Some students suggested initiating the individual (laboratory) projects earlier in the two-course sequence in order to allow more time for project completion.

Summary:

The advantages of both student team and individual project participation were achieved through implementation of a two-course sequence in bioengineering design. A high degree of course organization is required to meet comprehensive course goals. For both courses in the sequence, formal student requirements designed to enhance the students ability to communicate effectively include periodic individual oral and written reports. The association of significant grade credit with each report ensures a continuous student effort throughout both courses. Locating the individual student projects in the last semester before graduation promotes independent work at this point and allows for a student option to conduct pre-graduation research (as a preparation for graduate studies) in place of a design project.

References:

1. Jendrucko, R.J., "An Assessment of the Impact of Undergraduate Biomedical Engineering Education Based On A Survey of Training Programs", presented at the Biomedical Engineering Society 1974 Annual Meeting, New Orleans, April 12, 1975.